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SAFETY IN PETROLEUM MOVEMENT: IS ENOUGH BEING DONE TO PROTECT THE ENVIRONMENT?

by

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Thesis Advisor: Dan C. Boger

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Safety in Petroleum Movement: Is Enough Being Done to Protect the Environment?

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ABSTRACT

This thesis is an investigation to identify whether sufficient efforts are being taken to provide the highest possible safety in petroleum movement. Current practices and on-going initiatives for spill prevention and cleanup are identified. From these efforts, overall trends in spills have been identified. The small percentage of oil spilled, compared to the amount transferred is examined; in addition, long term impact on the environment is analyzed. It is concluded that oil spills are inevitable no matter how much effort is exerted; they are a part of petroleum movements. However, due to the concerted efforts by industry and government, spills should continue to decline via better prevention, and those spills that do occur will be cleaned up more promptly, with less environmental impact. The author recommends that efforts for oil spill reduction need to continue and require constant management attention. In addition, specific recommendations for the oil spill program are also included.

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I. INTRODUCTION

A. GENERAL OVERVIEW

The safety of petroleum movement: Is enough being done to protect the environment? How many spills are too many? How much effort can we (or do we) expect in order to preclude spill incidents? How much effort is necessary to ensure these undesirable events do not occur? Of course, we all would hope for zero spills, but is this attainable? A more appropriate question is, are concerted efforts being made to reduce oil spills and their impact on the environment, and are these efforts providing overall downward trends?

This paper will identify the U.S. government and industrial initiatives that are occurring to reduce the oil spill count and impact. The current identified causes, sources and developing oil spill trends will be discussed; in addition, the paper will compare the size versus the quantity of spills. With these statistics, problem areas can be identified and trends analyzed to show oil spill patterns.

The small percentage of spillage in comparison to total volume transported will be analyzed. In addition, the misperception of where the majority of oil spills comes from will be reviewed; i.e., are tanker accidents or industries/municipalities, which might be continually

"dripping" parts per million (ppm) of oil particles into the water, the major cause of oil pollution?

The overall impact of spilled oil in nature will be reviewed; do both nature and man contribute to the introduction and removal of oil? Are natural processes occurring each and every day degrading petroleum hydrocarbons?

Impact of the recently signed Oil Pollution Act of 1990 will be analyzed in depth. A cost/benefit analysis of the Act, to determine the impacts on industry (in addition to society and government) will be included. The opportunity costs and intangible benefits as a result of the Act will be addressed, in addition to a effectiveness evaluation. Potential alternatives also will be provided for consideration in spill reduction.

In summary, this paper will analyze the current oil spill situation to identify trends and provide statistics, enabling one to appropriately evaluate whether, given man's present capabilities (both technological and economical), enough is being done to protect the environment. The overall intent of this paper is to put the oil spill picture into a realistic perspective.

B. PURPOSE, LIMITATIONS, AND ASSUMPTIONS

When a major oil spill accident occurs, the public is informed: front page news is the norm. There is no doubt that major oil spills are undesirable and have immediate impacts on the environment and man. But, the "big picture" needs to be

assessed. What portion of all oil annually "dumped" into the water is accounted for by each individual spill: what <u>ultimate</u> impact will it have on both the environment and man? Putting spills into a proper perspective is critical, and this is the purpose of this paper.

The following limitations will be observed during this study:

1. Statistics provided by the U.S. Coast Guard and other sources are restricted by the information provided to them and the availability of current data.

2. Studies that are not performed annually, but rather a several-years basis, will provide overall trend statistics but do not provide any additional, more frequent "snapshots" of the data.

3. New developments occurring are restricted to published material of efforts being made. Unavailable, undisclosed technologies which industry and the government may be developing could also provide an additional (and currently not assessed) impact on the spill scene in years to come.

4. Statistics for potential future oil spill reductions (for example, the result of the double hull requirement by the year 2010 from the Oil Pollution Act of 1990) are only estimates, based on historical data, which cannot be fine-tuned to a great degree.

For the purpose of this study, the following assumptions will be made:

1. The published statistics on oil spills are accurate and not biased.

2. Industry and government activities will continue reduction efforts, in conjunction with new government regulations, to reduce potential oil spill costs as much as feasible.

3. The U.S. Government will continue to seek the most productive means (for both industry and the government) of monitoring industry and government facilities, and provide efficient/effective legislation for reducing spills as much as is technologically and economically credible.

C. MAJOR DATA SOURCES

The primary source of statistics for trends, sources, causes and general areas of spills is the U.S. Coast Guard. In addition, close liaison with several organizations, including the Pacific Strike Team (Navato, CA), the Oil Spill Response Team (Alameda, CA), and the Clean Bay Oil Spill Cooperative (Concord, CA) provided critical oil spill information. Finally, the Coast Guard Research and Development Center (Groton, CT) and the Naval Facilities Engineering Command, in conjunction with resources (i.e., periodicals) available locally provided information on oil spills, their prevention/cleanup, and technological programs under development.

D. THESIS ORGANIZATION

The remainder of this thesis is organized as follows:

1. Chapter II provides background on prevention methods and cleanup procedures. Information on the impact of oil on nature also will be included.

2. Chapter III describes the sources, general areas and causes of spills. Utilizing statistics provided from the U.S. Coast Guard for each of these areas, this chapter will identify problem areas, or the reduction thereof, and where emphasis should be concentrated.

3. Chapter IV will utilize the statistics from Chapter III and present overall trends for the oil spill categories in both quantity (gallons) and number. An analysis and interpretation of the statistics will also be provided.

4. Chapter V will identify initiatives being explored by both industry and government to reduce oil spills. It includes prevention and cleanup technological developments.

5. Chapter VI will analyze the Oil Pollution Act of 1990, providing a cost/benefit analysis and effectiveness evaluation. The impacts on industry, the government and society will be examined, and opportunity costs and intangible benefits will be identified.

6. Chapter VII will contain the conclusions and recommendations.

II. BACKGROUND

This chapter provides a comprehensive introduction to the properties of oil and their impacts on nature. Natural processes that affect oil are discussed, in addition to an overview of the sources of spills by man. Background information on types of spills, their cleanup and methods of prevention are addressed, in addition to spill characteristics, where spills can be expected, and the current fundamental procedures of cleanup and prevention. Later chapters will identify new innovations being developed to reduce spill incidents further.

A. INTRODUCTION

Oil enters the environment from both natural phenomena and man's activities. It has been observed that "seeps and erosion of geological sediments contribute petroleum hydrocarbons (oil) to the environment through natural processes" [Ref. 1:p. 2]. Man also releases oil in numerous ways, including accidental spills and "long term, low-level discharges associated with municipal and industrial wastes, petroleum production, and transportation activities" [Ref. 1:p. 2]. Finally, it has been noted that "organisms living in the sea also produce hydrocarbons through natural biological processes..." [Ref. 1:p. 2].

What is also of interest is that both nature and man contribute to "its (oil) removal or its dispersal into innocuous concentrations..." "Natural processes - physical, biological and chemical - degrade petroleum hydrocarbons" [Ref. 1:p 2]. As is well known, man contains and recovers spilled oil to the best of his capabilities.

Petroleum is "not a substance foreign to the marine environment...natural seeps have been discharging petroleum hydrocarbons into the marine environment for millions of years, in amounts substantially greater than those resulting, for instance, from present-day offshore production activities" [Ref. 1:p. 3]. To date, about "200 submarine oil seeps have been identified around the world...petroleum has continuously entered the seas as a result of the erosion of uplifted sedimentary rocks containing trace amounts of petroleum hydrocarbons" [Ref. 1:p. 3].

Of note is the fact that "most surface and near-surface open ocean water contain petroleum hydrocarbons in the range of about 1 to 10 parts per billion (ppb),...deeper open ocean waters...are 1 ppb or less...(and) coastal waters...show higher...levels...up to 100 ppb" [Ref. 1:p. 3]. However, these levels "appear to have little, if any, toxic effect on marine life...concentrations from 10 to 100 times greater than coastal waters are required before measurable effects on marine organisms can be detected" [Ref. 1:p. 3].

Many different processes act on a spill that impact its cleanup or removal. Evaporation is a primary process; it is "responsible for the loss of up to 500 percent of a surface oil slick's volume..." [Ref. 1:p. 6]. Of critical significance to marine life, is that "benzene, toluene, and xylenes, which are rapidly lost through evaporation, are among the most toxic components in oil" [Ref. 1:p. 6]. Consequently, this drastically reduces the impacts of oil on ocean life forms. Some organisms "ingest dispersed oil droplets...bacteria, yeast, and fungi (are) capable of metabolizing and chemically degrading petroleum hydrocarbons..." [Ref. 1:p. 9]. Photo-oxidation, in which oil films oxidize, also occurs. In fact, "40 barrels spread over a square mile could be degraded in a few days by photo-oxidation" [Ref. 1:p. 9].

In addition, three facts of importance have been exposed through research:

> -there has been no apparent irrevocable damage to marine sources on a broad scale by either chronic inputs of oil or occasional major oil spills...
> -where oil has had an effect,...monitoring has shown...biological recovery...(which can take weeks, months or years, depending on the spill and its location)
> -there is no evidence...of a deleterious impact on human health from releases of petroleum into the marine environment. [Ref. 1:p. 9]

Oil enters the water from many different sources controlled by man. Of critical note is that only 12.5 percent of oil spilled is from tanker accidents, while 31.3 percent is from industrial and municipal wastewater discharges and run-

off. Natural seeps and erosion account for approximately 8 percent of oil in the sea, and atmospheric fallout (from trace amounts of petroleum which have evaporated into the atmosphere) accounts for almost 10 percent. Refinery wastewater, offshore oil production and other transportation operations account for the remainder [Ref. 1:p. 2]. All this is important to realize, because when one first thinks of an oil spill, one usually thinks of a tanker accident. Such accidents only account for about one-eighth of all spills [Ref. 1:p. 2] (see Figure 1).

B. TYPES OF SPILLS AND THEIR CLEANUP

Any place oil is stored, transferred or shipped, there is a potential for a spill. Spills occur in pipelines, hoses, valves, and loading arms. Ruptured tanks, barges, and tankers are not unheard of. Fuel movements by rail or truck also pose risks for spills.

Spills occur on land, harbor areas, rivers, lakes and the open ocean. "Spills of petroleum products on land rank with beach areas as the most difficult, time consuming and expensive spills to effectively clean up" [Ref. 2:pp. 3-103]. The main concern is the "leaching of the product to a ground water supply" [Ref. 2:pp. 3-17]. Consequently, spills occurring in harbor areas, rivers, and lakes need to be prevented from reaching the shoreline, due to the high cost and difficulty in cleanup. Spills also occur on ice and snow

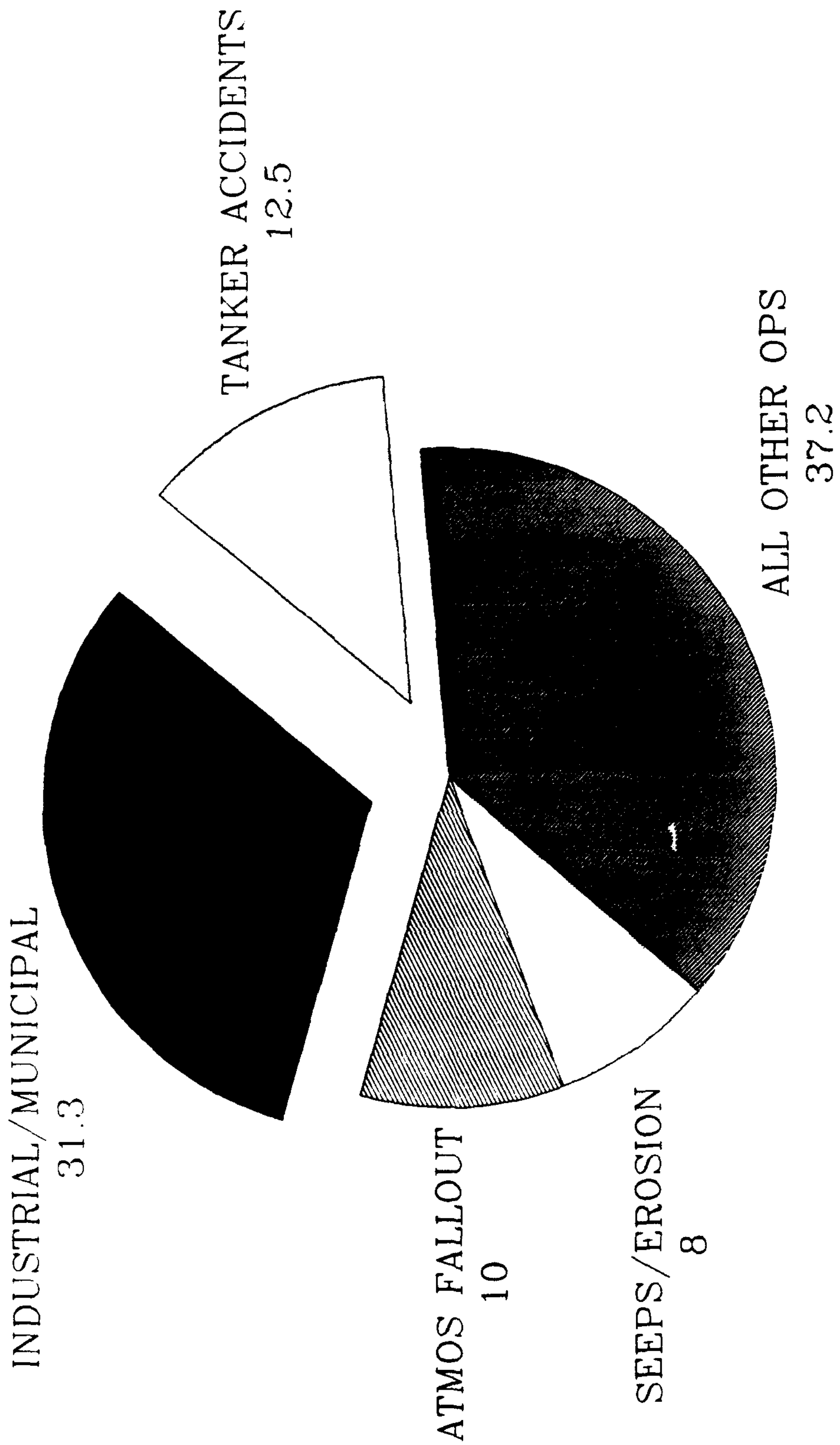

Figure 1

Sources of Spilled Oil (By Volume)

(although "snow is a good sorbent" [Ref. 2:pp. 3-107] allowing for easy disposal). Spills spread until they are contained, broken up (i.e., by wave action) or evaporate (only the less viscous products or components evaporate). Small spills are typically not a serious threat. However, large spills of the magnitude of the Exxon Valdez or the Persian Gulf conflict necessitate massive cleanup efforts.

The first priority when confronting an oil spill is to "make all possible efforts to limit the spread of the oil mass" [Ref. 2:pp. 3-36]. Cleanup equipment needs to be readily available, so as to be promptly on-scene. Equipment includes skimmers, booms, and tow assemblies. Personnel need to be well trained and be equipped with effective communication capabilities.

Oil slicks move at the speed of the local surface current and at approximately three percent of the wind velocity [Ref. 2:pp. 3-89]. Consequently, prompt deployment of boom, skimmer and utility boats to enclose the spill and protect the shorelines cannot be overemphasized. Whenever possible, booms should be deployed in such a way that "skimmers can be located downwind" [Ref. 2:pp. 3-89] of the slick. Water jets from utility boats or from pierside fire trucks can be utilized to direct the slick into a skimmer for retrieval and away from shorelines. Also, "since oil does not adhere well to wet surfaces...hose down rocky areas before the arrival of an oil slick" [Ref. 2:pp. 3-101]; this can aid substantially in the

cleanup process. A "less desirable approach is to use a hot, high pressure (120 degree Fahrenheit, 1200 psi) water jet...to loosen oil adhering to rocks and push it back in the water to be picked up by skimmers" [Ref. 2:pp. 3-103].

In cleaning oil from fast current rivers and tidal areas, the first step is to "divert the oil out of the fast current into areas of low current" [Ref. 2:p 3-103].

Cleanup of land spills includes the use of vacuum trucks and sorbent pads with the proper disposal of oil-soaked soil.

In summary, oil spills occur quickly and without notice. It has been estimated that it costs about "$6.50 to cleanup one gallon of oil" [Ref. 2:p. 3-2]. Consequently, prompt, effective cleanup capabilities, especially the basic procedures described in this section, need to be in-place wherever a spill is capable of occurring to reduce the full potential of damage from the spill as much as possible.

C. METHODS OF PREVENTION

"Prevention is not only far more important than all the skimmers and floating booms, it is cheaper, too" [Ref. 2:p. 3-2]. Prevention is a key aspect of fighting oil spills. It includes having adequate containment to prevent the oil from reaching navigable waters; examples are dikes, berms, curbing, and retaining walls (all impervious to oil).

Tanks, including supports and foundations need to have "integrity testing...using hydrostatic testing, visual inspection or a system of non-destructive shell thickness

testing" [Ref. 2:pp. 3-53]. Consideration should be given to having one or more of the following: high liquid level alarm, high liquid level pump cut-off devices and/or a fast response system for determining the liquid level [Ref. 2:pp. 3-25-3-26]. "Buried piping installations should have protective wrapping and coating and be cathodically protected if soil conditions warrant...pipe supports should be properly designed to minimize abrasion and corrosion and allow for expansion and contraction" [Ref. 2:p. 3-26].

All above-ground tanks, valves, and pipelines require frequent visual examination and should be clearly marked to prevent misalignment during oil transfer operations [Ref. 2:p. 3-31]. Hose assemblies require a minimum bursting pressure of 600 pounds per square inch, and they need to be properly marked, identifying product, last test date and pressure [Ref. 2: p. 3-7].

Hoses need to also be supported "in a manner that prevents strain on couplings" [Ref. 2:p. 3-14]. Loading arms, which are used to load and offload fuel from vessels, must meet specific testing requirements and have some means of draining or being closed before disconnecting after transfer of oil [Ref. 2:p. 3-9].

Additional prevention measures include emergency shut down capabilities, adequate lighting, and communication.

All of these fundamental prevention measures assist in keeping the spill count and volume to a minimum. As

additional industrial and government initiatives occur (these will be discussed in later chapters) oil spill incidents should decrease even more. The significance of new methods of prevention cannot be overemphasized. They can have a tremendous impact on reducing the amount of oil spilled and its associated high cleanup cost.

III. SOURCES, GENERAL AREAS, AND CAUSES OF SPILLS

In this section, oil spills will be analyzed from a variety of aspects. Data accumulated on sources of oil spills will provide information on the place from which the oil spill comes from; i.e., from land vehicles, vessels or facilities. The general area of spills will be examined, providing statistics on significant locations where oil spills have occurred; i.e., inland, the Atlantic Ocean, the Pacific Ocean and the Gulf of Mexico. In addition, another critical aspect of oil spills is their cause. By examining this aspect of oil spills, the most prevalent reasons for the spills can be determined and provide areas for future work.

A. SPILL SOURCES

The sources of oil spills will be scrutinized first. Statistics provided by the U.S. Coast Guard reflect a decreasing percentage of oil spills in both the land vehicles and facilities categories while the number of spills resulting from vessels has been steadily increasing. In 1982, approximately 49% of all oil spills (number of incidents) were from facilities, and approximately 10% were from land vehicles; the remaining 41% occurred from vessels [Ref. 3:p. 9]. In 1984, facility spills accumulated about 45%, vessels had 44% and the remainder was from land vehicles; in 1986, 54% were a result of vessel spills, about 7% were from land

vehicles and 39% were from facilities [Ref. 3:p. 9]. From these statistics (see Table I), one notes the decline in

TABLE I
OIL SPILL INCIDENTS (%)

SPILL SOURCE	1982		1984		1986	
	%	No. of Incidents*	%	No. of Incidents*	%	No. of Incidents*
FACILITIES	49	5390	45	5625	39	2925
LAND VEHICLES	10	1100	11	1375	7	525
VESSELS	41	4510	44	5500	54	4050
TOTALS	100	11,000	100	12,500	100	7,500

*Numbers are approximate figures

facility spills' percentages and the slowly increasing percentage of oil spills from vessels in recent years. In addition, oil spills, by volume, had a similar pattern between the years 1982-1986. In 1982, roughly 65% of the volume of the spills were from facilities, 30% from vessels, and 5% from land vehicles; in 1984, 42% resulted from facilities, 54% from vessels and 4% from land vehicles; and for 1986, about 69% of spills were from vessels, with 30% from facilities and approximately 1% from land vehicles [Ref. 3:p. 9] [Ref. 4:Attachment 1, p. 1] (see Table II).

TABLE II
OIL SPILLS, BY VOLUME (%)

SPILL SOURCE	1982		1984		1986	
	%	Volume	%	Volume	%	Volume
FACILITIES	65	6,763,020	42	6,827,089	30	1,400,533
LAND VEHICLES	5	520,232	4	650,199	1	46,684
VESSELS	30	3,121,394	54	8,777,686	69	3,221,224
TOTALS	100	10,404,646	100	16,254,974	100	4,668,441

These statistics appear to reflect (as shown in Figures 2 and 3) an improved awareness in recent years at the facilities and land vehicles, and identify the need to more closely monitor vessel spills, to keep them in check.

B. GENERAL AREAS OF SPILLS

Similar conclusions can be reached by analyzing the general areas of spills. In 1984, 21% of oil spills (by number of incidents) occurred inland, (i.e., rivers, lakes, on land) while 59% occurred on the oceans (21% in the Atlantic Ocean, 21% in the Gulf of Mexico and 17% in the Pacific); the remaining percentage was not identified [Ref. 3:p. 14]. In 1985 the inland percentage was 19%, 56% was in the oceans, and the remainder was not identified; in 1986, the inland percentage dropped to 11%, while the oceans had 53% (19% in the Gulf of Mexico, 17% in the Atlantic Ocean and 17% in the

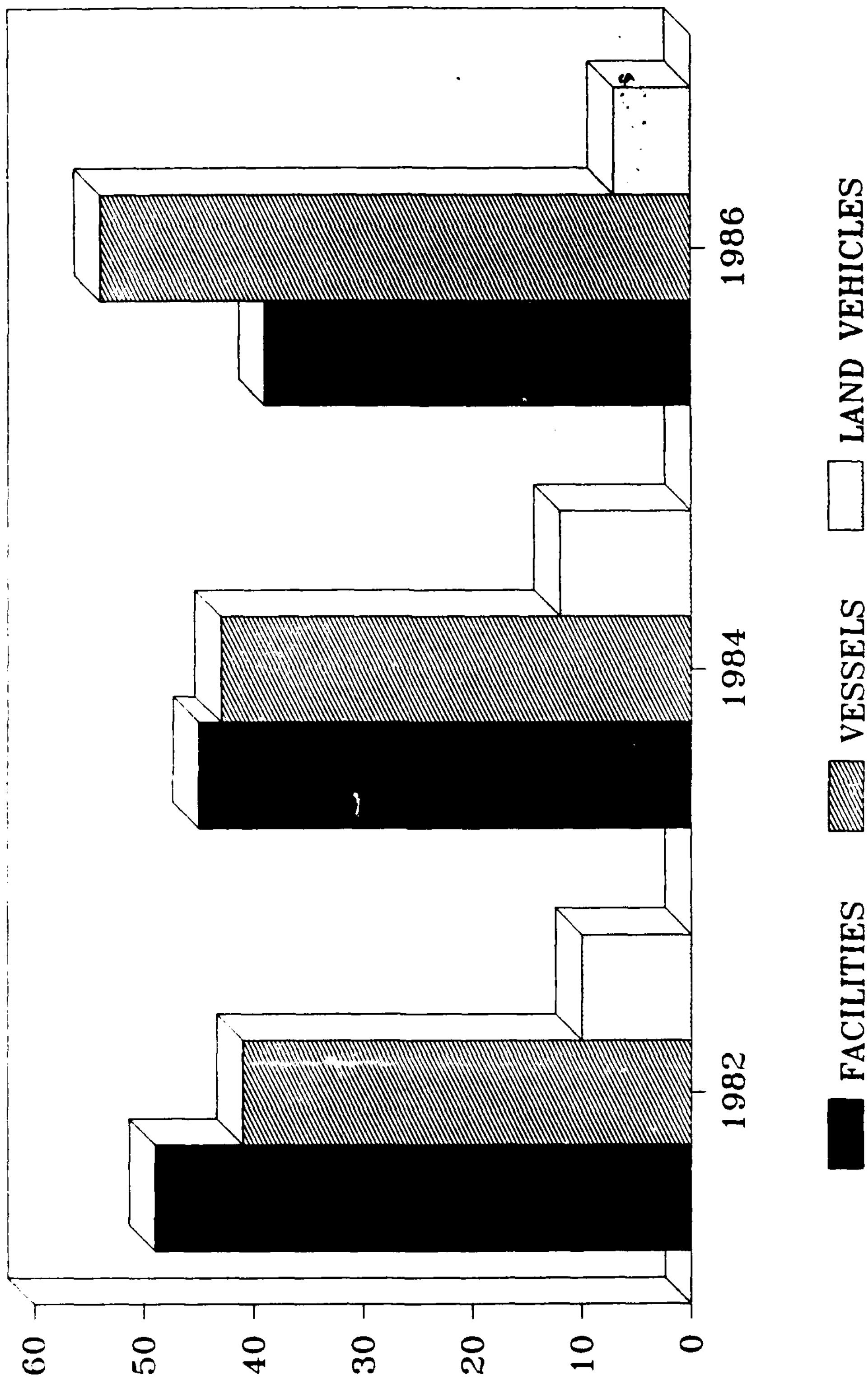

Figure 2
Oil Spill Incidents (Percentage)

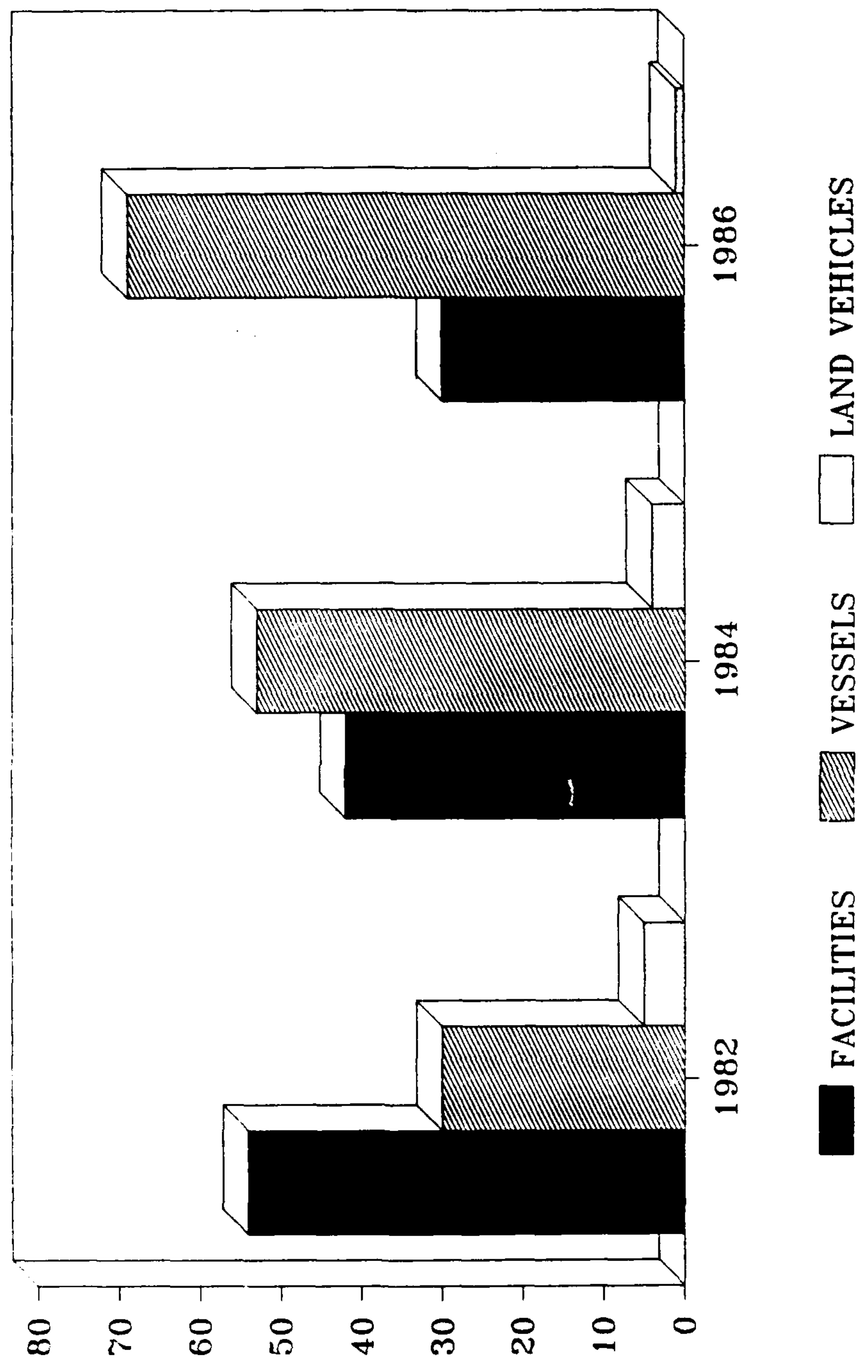

Figure 3
Oil Spill Volume (Percentage)

Pacific Ocean); again the remaining percentage was not identified [Ref. 3:p. 14] (see Table III). These statistics identify a need to monitor and place more attention on the oceans, and their coasts, than the inlands.

TABLE III
GENERAL AREAS OF SPILLS (%)*

AREA	1984	1985	1986
INLAND	21	19	11
WATER AREA:			
ATLANTIC OCEAN	21	16	17
PACIFIC OCEAN	17	20	17
GULF OF MEXICO	21	20	19

*Remaining percentage is not identified by the U.S. Coast Guard

Another dimension for analyzing the oil pollution incidents by location includes comparing the water territory for the spills. River channels, encompassing 31% of the number of spill incidents in 1984, retained a high percentage in 1985 (30%) and 1986 (29%) [Ref. 3:p. 16] (see Table IV). Also, of interest is the fact that in 1984, 25% of spills measured in gallons occurred in river channels and this grew to 47% in 1986 [Ref. 3:p. 17]. These statistics reflect a need for more attention to be placed in the river channel locations. Of importance is the fact that ports and harbors reduced from 21% in 1984 to 16% in 1985 and to 7% in 1986; the territorial seas (shore-3 miles) reduced from 21% in 1984 to 20% in 1985 to 9% in 1986; the remaining percentages included open sheltered, contiguous zone (3-12 miles), high seas (12

miles or more), and that which was not identified [Ref. 3:p. 16] (see Table IV). These statistics identify the attention being placed in the ports and harbors and the territorial waters.

A detailed analysis of the origin of spills provided further information on oil incident statistics. Table V shows the relative percentages. Between 1984-1986, oil spills from tank ships and tank barges rose in quantity (from 11% to 26.2% for ships and from 15.3% to 42.4% for barges) [Ref. 3:pp. 47,49]. This identifies a need for attention in this oil spill area. Most all other areas had a decline for this time period, i.e., bulk storage reduced from 9% to 7.9%, land vehicles reduced from 1.7% to .8%, rail reduced from .5% to negligible, off-shore production remained at .3%, on-shore production changed from .1% to .2% (a modest increase), bulk

TABLE IV
WATER TERRITORY OF SPILLS (%)*

AREA	1984	1985	1986
RIVER CHANNELS	31	30	29
PORTS AND HARBORS	21	16	7
TERRITORIAL SEAS	21	20	9
OPEN SHELTERED	13	12	12
HIGH SEAS	9	6	**
CONTIGUOUS ZONE (3-12 MILES)	5	5	**

*Remaining percentage not identified by the U.S. Coast Guard
**Not identified by the U.S. Coast Guard

TABLE V
ORIGIN OF SPILLS (%)*

SPILL SOURCE	1984	1986
VESSELS		
TANK SHIPS	11	26.2
TANK BARGES	15.3	42.2
DRY CARGO BARGES	0.0	0.0
DRY CARGO SHIPS	9.1	0.8
COMBATANTS	1.0	0.6
OTHER	1.4	6.4
LAND VEHICLES		
RAIL	0.5	0.0
HIGHWAY	1.7	0.8
OTHER	0.2	0.0
NON-TRANSPORTATION		
BULK STORAGE	9.0	7.9
REFINERY	0.9	6.1
ON-SHORE PRODUCTION	0.1	0.2
OFF-SHORE PRODUCTION	0.3	0.3
OTHER	1.4	0.2
TRANS/RELATED PIPELINES	0.0	3.9
MARINE FACILITIES		
FUEL TRANSFER	0.1	0.0
BULK TRANSFER	0.5	0.0
NON-BULK TRANSFER	0.0	0.0
OTHER	0.0	1.8
LAND FACILITIES	0.2	0.5

*Remaining percentage not identified by the U.S. Coast Guard

transfer reduced from .5% to negligible [Ref.3:pp. 47,49]. These statistics appear to indicate an increased attention having been placed in these areas.

C. SPILL CAUSES

Causes of spills are of great concern and are critical for establishing problem areas. Table VI shows the relative percentages. The most drastic increase in cause of oil spills

TABLE VI

SPILL CAUSES (%)*

CAUSE	1984	1986
HULL RUPTURES	19.4	39.1
TANK RUPTURES	5.2	13.5
TRANS PIPELINE LEAK	3.2	4.0
OTHER STRUCTURE FAILURE	4.4	9.0
PIPE RUPTURE/LEAK	1.3	1.4
HOSE/LOAD ARM	0.3	9.4
VALVE FAILURE	1.0	16.2
PUMP FAILURE	0.3	0.6
OTHER EQUIPMENT FAILURE	0.9	0.7
TANK OVERFLOW	1.8	3.8
IMPROPER EQUIPMENT OPERATION	1.3	1.3
PERSONNEL ERROR	7.4	1.5
RR/HIGHWAY/AIR	2.3	0.9
BILGE PUMPING	0.0	0.1
OTHER INTENT	0.6	1.4
NATURAL	0.2	0.0

*Remaining percentage not identified by the U.S. Coast Guard

was from hull ruptures; in 1984, 19.4% (in quantity) of oil spills were caused by hull rupture, while in 1986, 39.1% had this cause [Ref. 3:pp. 51,53]. This sends a definite message of where concentration needs to be directed. In addition, tank rupture (i.e., at bulk storage facilities) also increased from 5.2% in 1984 to 13.5% in 1986, as did valve failures, (i.e., at ships, barges, bulk storage facilities) from 1% to 16.2%, and hose/load arm, (i. e., at bulk storage facilities)

from .3% to 9.4% [Ref. 3:pp. 50,52]. Most other areas had a decline: pipeline rupture/leak declined from 1.3% to 1%, improper equipment operation did not change at 1.3%, personnel error dropped from 7.4% to 1.5%, railroad/highway/air dropped from 2.3% to .9%, tank overflow had a slight increase from 1.8% to 3.8%, equipment failure (including pumps and other equipment) increased slightly from 1.2% to 1.3%, and natural causes reduced from .2% to negligible [Ref. 3:pp. 50,52].

In summary, the most significant areas of concern are: the oceans, (and their coasts), river channels, tank ships, barges and hull ruptures. In addition, current efforts being undertaken to reduce the spills in the above mentioned categories also will be examined in a later section of this paper.

In general, as the following statistics in this section will reflect, oil spills have decreased in both volume (millions of gallons) and in number. This is significant because even though a category of an oil spill, as discussed in the previous section, may have increased in percentage with respect to a total of 100% for oil spills, a <u>lower cumulative total</u> in number and quantity reflect an oil-conscious industry that is making changes to reduce oil spills.

One overall oil spill trend identifies that the number of total oil spills has decreased in number, from over 15,000 in 1978, to about 14,500 in 1979, to about 12,500 in 1980, to about 12,000 in 1981, to about 11,000 in 1982, to about 12,400

in 1983, to about 12,500 in 1984, to about 9,500 in 1985, to about 7,500 in 1986 [Ref. 3:p. 9] (see Table VII and Figure 4). In addition, two categories of spills have had the most significant impact on this drop in total number of spills: spills over 100 gallons (which dropped from about 2200 in 1982 to about 1000 in 1986) and spills that create only a sheen (typically less than one gallon) which decreased from about 3500 in 1982 to about 1200 in 1986 [Ref. 3:p. 9]. Spills in the 1-99 gallon range did not change substantially [Ref. 3:p. 9] (see Table VIII). These statistics appear to reflect the fact that more attention is being given to the prevention of spills of large volumes and sheens.

TABLE VII
SPILL INCIDENTS*

YEAR	NUMBER
1978	15,000
1979	14,500
1980	12,500
1981	12,000
1982	11,000
1983	12,400
1984	12,500
1985	9,500
1986	7,500
*NUMBERS ARE APPROXIMATE FIGURES	

TABLE VIII
OIL SPILL TRENDS (NUMBERS)*

SPILL SIZE	1982	1986
SPILLS OVER 100 GALLONS	2,200	1,000
SPILLS THAT CREATE A SHEEN	3,500	1,200
SPILLS: 1-99 GALLONS	4,800	4,900
*NUMBERS ARE APPROXIMATE FIGURES		

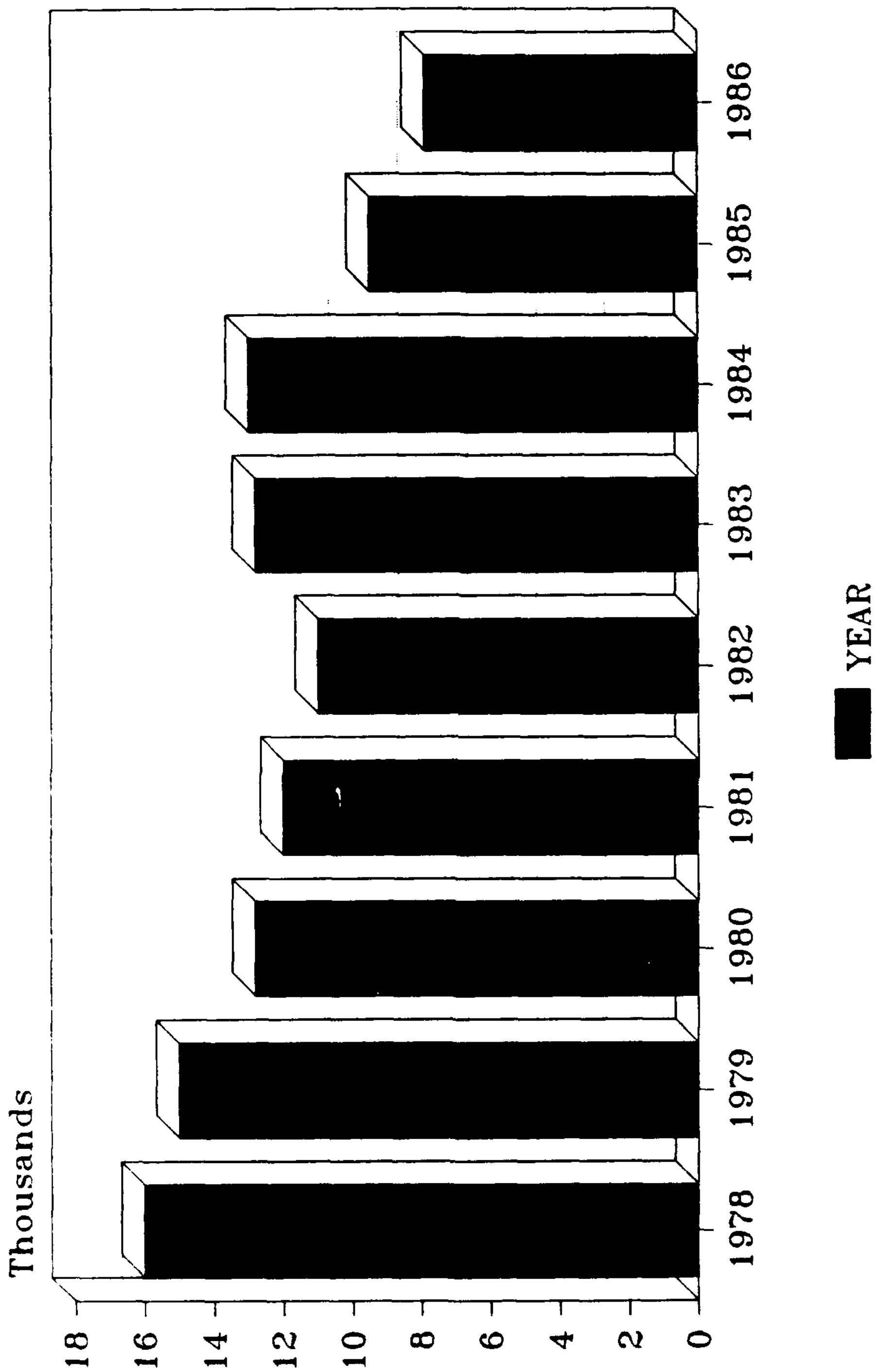

Figure 4

Total Oil Spills (Number)

In addition, the overall trend of quantity of oil spilled has decreased. In 1984, over 16,250,000 gallons were spilled; in 1985, over 18.5 million gallons; in 1986, about 4.7 million gallons; in 1987, about 4.3 million gallons; and in 1988 about 6.6 million gallons were spilled [Ref. 4:Attachment 1, p. 1] (see Table IX and Figure 5). This is a positive trend, and appears to identify an improved awareness and effort to decrease oil spills.

Further statistical analysis identifies that, in 1984, 78.9% of the volume of all spills resulted from 18 spills over 100,000 gallons (for a total of over 12 million gallons); this dropped to 2.75 million gallons (62.1%) for 12 spills over 100,000 gallons in 1986 [Ref. 3:pp. 53,55] (see Table X). This data also reflects the decline in major oil spills during this time period.

TABLE IX
TOTAL VOLUME OF OIL SPILLS

YEAR	VOLUME IN GALLONS
1984	16,254,974
1985	18,675,138
1986	4,668,441
1987	4,332,322
1988	6,640,851

Figure 5
Total Volume Of Oil Spills (Millions of Gallons)

TABLE X

STATISTICS FOR SPILLS OVER 100,000 GALLONS

CHARACTERISTIC	1984	1986
NUMBERS OF SPILLS	18	12
TOTAL GALLONS SPILLED	12,820,201	2,758,120
PERCENTAGE VOLUME OF ALL SPILLS	78.9	62.1

Moreover, the overall number of reported oil spills from barges, tankers, and all vessels has been declining "as a percentage of total oil spills into water, which have also been declining" [Ref. 5:p. 53]. It has been observed that the number of barge spills exceeds tanker spills every year. Of interest is the fact that, for "8 of 12 years the total volume spilled from them (barges) exceeded the volume spilled by tankers..." [Ref. 5:p. 53]. A significant note is the fact that "oil spills per vessel have declined 45 percent in the last 15 years..." [Ref. 5:p. 53].

In summary, the oil spills have decreased. The overall lower cumulative totals for both the number of spills reflect the concerted efforts of an oil-spill-conscious industry. As will be discussed in later chapters, many initiatives are underway to maintain these downwards trends. These efforts should also provide better cleanup capability.

IV. SAFETY AND THE REALITY OF OIL SPILLS

A. A REALISTIC PERSPECTIVE

As has been previously noted, industry performs regular preventive maintenance on vessels, storage facilities, and land vehicles and practices oil movement safety to keep spills to a minimum. The overall downward trends reflect a concerned industry, attempting to control the oil spill situation. Realistically, the oil spill picture is not as dismal as some media may depict.

To put the oil spill picture in a proper perspective, it has been revealed that "one five-hundredths of one percent of the total amount of oil moving through U.S. waters is spilled" [Ref. 6:p. 15]. This is a very small percentage, and as Steve Ricks, from the Clean Bay Oil Spill Cooperative (in Concord, CA) stated: the amount of oil spilled in the Exxon Valdez accident is equivalent to about three days of what normally enters the water throughout the world by all means (i.e., industry, municipalities, erosion, seeps...as identified in Chapter II).

The world uses over "60 million barrels of oil each day...(3.5 trillion liters per year)...the oil spilled by the Exxon Valdez amounts to 4/10 of 1 percent of the world's daily use" [Ref. 7:p. 660]. In addition, "tankers had made nearly 9000 trips from Valdez with a accumulation of 6.7 billion

barrels (281 billion gallons) oil in the past 11 years without a major incident" [Ref. 8:p. 47]. For the Valdez spill, most of the deaths of the sea birds and otters occurred shortly after the spill; the "long-term injury to most wild-life and marine organisms is expected to be minimal..." [Ref. 8:p. 62].

The potential for a major accidental spill such as from the Exxon Valdez had a probability of "once in 241 years" [Ref. 10:p. 68]. As a comparison, the Exxon Valdez spill of March 1989 spilled about 240,000 barrels of crude (an accident) while the spill in the Persian Gulf (1991), called the largest spill in history, has been estimated at six to eight million barrels [Ref. 10:p. A6]. The latter was definitely not an accident. One must keep in mind, as was discussed in Chapter II, that oil is a naturally occurring mineral product that does not contain "PCB's, plutonium or chlorine gas...". In addition, the earth recycles carbon and carbon-based materials. In large quantities, they cause serious disruption for a time, but there is no evidence that they cause permanent damage" [Ref. 7:p. 660].

The "number of pollution-causing tanker accidents as recorded by the U.S. Coast Guard has fallen over 50 percent in the 1980s, suggesting that safety is improving" [Ref. 11:p. 46]. These statistics are significant and merit attention; they reflect the fact that significant efforts are being made to decrease oil spills. As the pursuit of perfection in this field continues, its goal of zero spills may never materialize

(due to realistic technological and economic constraints) as long as oil continues to be transported.

Moreover, more oil movement results in a higher potential for spills. Today, more petroleum is being imported into the U.S.; 33% came from overseas in 1973, while 46% came in 1990. The U.S. has been producing oil for over 130 years and its biggest and best oil fields are being pumped dry; it is also unlikely more giant oil fields will be found in the United States [Ref. 12:p. 38]. The need for research and development to search for oil fields, and provide the highest capability to preclude and cleanup spills must be continued, especially because of this increased oil transportation/movement trend. Oil spills must never take a "back-row" seat.

Although spills are a part of the oil industry, many innovations, by both industry and government, are being investigated and developed to reduce the risk of spills. These developments are identified in the next chapter.

B. SAFETY

It has been observed that there has been "a declining rate of vessel casualties, a declining rate of vessel losses as a result of accidents, and a declining rate of personnel injuries" [Ref. 5:p. 35]. These safety trends are significant in light of the fact that during the same 20-year period, the average crew size has declined substantially (from the "low thirties to below twenties for U.S. flag vessels, and the high teens for many foreign fleets)" [Ref. 5:p. 35]. Many advances

have occurred to promote these trends: technology has improved, operating procedures have been refined, and the scrutiny of maritime operations by government and industry bodies has increased" [Ref. 5:p. 35]. In addition "worldwide casualty rates of large tank vessels have declined...(to) a level roughly 20% below those of the mid to late 1970's" [Ref. 5:p. 42]. For tankers, "total (vessel) losses have since (the 1970s) declined to half the prior levels, perhaps indicating that safety measures adopted...are having the desired effect" [Ref. 5:p. 45]. The tanker casualty rate, identified in incidents per thousand tons, "marked declines of over...50% for tankers" (see Figure 6) [Ref. 5:p. 45]. In addition, in the past years "injuries per million man-hours worked...have declined 50 percent", [Ref. 5:p. 54] and this has occurred even though the number of employees has decreased per vessel.

The overall opinion of vessel operators is that safety has improved aboard ships, even with smaller crews, because of greater safety consciousness and improved equipment. "Crew reductions require better trained personnel who are able to accept more responsibility and to manage automated systems" [Ref. 5:p. 60]. Of important note is that average working hours do not need to increase, and fatigue can actually decrease, if these smaller crew vessels are properly managed. For example, because of automated power plants, the average engine department has reduced from 8 to 5 personnel. Before

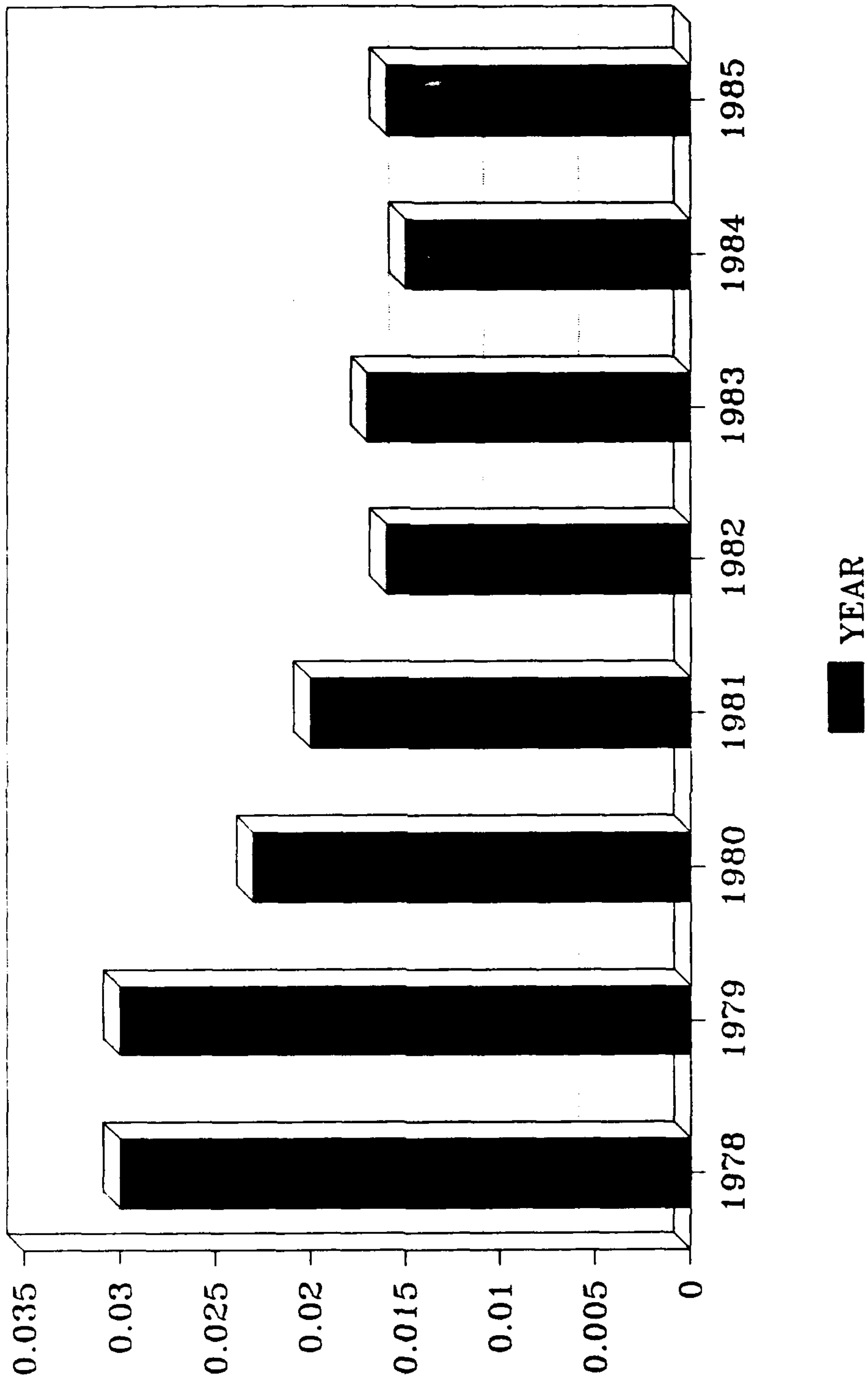

Figure 6
Tanker Casualty Rate
(Incidents Per Thousand Tons)

automation, six of the eight were watchstanders, with an average day of 11-1/2 hours; with automation, all 5 members stand day watches, averaging 10-1/2 hour days, allowing for all to work together as a team, and have the same meal and recreation times [Ref. 5:p. 102].

The use of ergonomics in designing new systems can assist in reducing fatigue, thus providing a potential to also improve safety statistics [Ref. 5:p. 68]. In addition, the use of "dead man" switches and alarm systems to "guard against lapses in attention or sudden incapacitation" [Ref. 5:p. 88] are very effective safeguards in the prevention of accidents.

Even with smaller crews, maintenance remains critical in ensuring good shipboard safety. Newer materials and changes in design have eliminated some routine work or made them shipyard repair items. To perform maintenance, some companies employ "riding crews" or employ firms to perform needed maintenance in port. [Ref. 5:p. 63]

Reduced crew sizes result in less on-the-job training opportunities onboard the vessel. Consequently, personnel need to be well-trained prior to boarding the vessel. Some companies have "instituted cadet programs to train unlicensed personnel....others hire in excess of the normal compliment until crew members gain the necessary experience" [Ref. 5:p. 65]. The recruiting of maritime academy graduates also occurs to obtain better qualified personnel. Finally, many new automated shipboard systems have "built-in capabilities for

individual and team training which permit operators to simulate training exercises and mentally rehearse typical and atypical situations" [Ref. 5:p. 92]. In addition, courses (some using simulators) in ship handling, stress and team management, technical engineering competence and oil spill cleanup and containment are utilized at union-run schools and at the U.S. Merchant Marine Academy [Ref. 5:pp. 99-100].

To promote safety and identify the impact of reduced manning on the social environment, psychologists have been used to clarify the situation to crews by providing training and counseling [Ref. 5:p. 80].

In addition, there is "no evidence to suggest that drug and alcohol abuse has increased during the past 30 years" [Ref. 5:p. 84] even while crew size has decreased. In 1988, the Coast Guard issued the "Programs for Chemical Testing of Commercial Vessel Personnel" (CGD 86-067), requiring employers to have drug and alcohol control programs, including "testing before employment, after accidents, and under other specified conditions" [Ref. 5:p. 84]. Regulations "prohibit a crew member's standing watch if he or she has consumed alcohol within the previous 4 hours...(in addition), companies are...required to have alcohol test kits on board, with personnel trained in their use" [Ref. 5:p. 84], to test the crew as deemed necessary. Because, small crews imply "greater mutual dependence for safe operation, peer pressure to be sober and fit for duty" [Ref. 5:p. 89] is stronger.

In summary, with appropriate training, organizational innovations, and ergonomic design, new vessel technology will not degrade safety. In fact, these efforts can "reduce the potential problems of stress, fatigue and boredom" [Ref. 5:p. 103]. As a result, this can only increase the safety aspects of the vessel. Moreover, safety is of utmost importance to vessels in reducing the potential for spills. With technology and safety improving, spill reduction can be expected to continue.

V. OIL SPILL INITIATIVES FOR PREVENTION AND CLEANUP

A. INDUSTRY AND GOVERNMENT EFFORTS

Many new developments have occurred and others are being investigated to reduce the number and volume of spills, in addition to providing a more efficient and effective cleanup capability. These efforts are wide and varied and will be discussed in detail in this section. Programs such as Strike Teams and Oil Spill Cooperatives will also be examined to assess their potential impact on spills.

Research and testing is a regular occurrence in the oil spill prevention and cleanup areas. Some new developments include: Du Pont recently unveiled a "composite liner system for cargo tanks to prevent spillage if the outer metal hull is penetrated" [Ref. 13:p. 16]. M.H. Systems, of Del Mar, California, has discussed a "retrofit system for tankers to limit spillage to the volume below the line rupture" [Ref. 13:p. 16]. The Swedish National Maritime Administration has proposed a "system for pressure/vacuum relief valves to minimize escape of oil from damaged cargo tanks" [Ref. 13:p. 16]. Automated Response Systems has proposed a "water filled buffer bag retrofitted in the bottom of cargo tanks" [Ref. 13:p. 16]]. Ocean Clean, Inc., has disclosed "plans for a ship mounted system to recover oil and store it in a flexible, floating bag" [Ref. 13:p. 16].

Shell Oil and Crowley Maritime recently developed a "self-contained oil spill contingency barge...which could (in theory) have contained, removed and stored 30% of the crude oil which flowed out of the stricken ship" (Exxon Valdez) [Ref. 14:p. 89]. This barge represents the "leading edge in mobile oil-recovery capability" [Ref. 14:p. 89]. It was used in the summer of 1990 as a key element of the spill contingency plan during "exploratory drilling in the Chukchi Sea" [Ref. 14:p. 89]. Its large size offers stability at sea. It has "significant below-deck liquid storage, deck stowage for spill-response vessels and adequate room for mobile crane operations and boom deployment" [Ref. 14:p. 89].

The Navy has recently procured newly developed Crowley Environmental-Alden Industries Model A-4 skimmers which are to be used to cleanup spills less than 200 gallons [Ref. 15:p. 1]. They are most useful near "piers, berthed ships, ditches, ponds, and shore areas with water depths of less than 4 feet" [Ref. 15:p. 1]. A skimmer is lightweight and compact (it fits into a pick-up truck), can be used in harbor chop up to one foot, and is capable of being operated unattended [Ref. 15:p. 2].

A vacuum tank system is being researched which could "significantly reduce the volume of oil escaping in a grounding" [Ref. 16: p. 42]. When the bottom of a ship is opened, there is an outflow of oil, creating an under-pressure. If a "vacuum is created by valves on the top of the

tank, this under-pressure would reduce the outflow because a hydrostatic balance would result" [Ref. 16:p. 42].

A new sensor package has recently been mounted to the HU-25B (U.S. Coast Guard aircraft) which is a "valuable asset in tracking oil spills along the U.S. coastlines" [Ref. 17:p. 36]. It has been used for identifying areas with an "oil thickness of greater than 2 micrometers" [Ref. 17:p. 56].

At Leonardo, New Jersey, Minerals Management Service is completing an oil spill test site (currently scheduled for completion in 1991) to improve spill cleanup capabilities in the United States. It has a "675 ft. by 65 ft. open air tank 11 feet deep that can hold 2.6 million gallons of salt water and simulate a range of sea conditions...(it) allows evaluation of equipment to detect, monitor, and cleanup spills [Ref. 18:p. 30].

Research in bioremediation is showing increased promise in assisting spill cleanup. A "controlled demonstration... showed microbes reduced oil concentration by 99.99% in a column of sea water" [Ref. 19:p. 20]. They can penetrate "depths of as much as 2 ft...to degrade subsurface oil" [Ref. 3:p. 20].

Another recent advance in cleanup techniques includes a "boom that can skim oil while also containing it" [Ref. 20:p. 1]. An emergency seal for leaking fuel containers has also been developed. It "forms an immediate seal to control...leaks and spills" [Ref. 21:p. 1]. The combination

of a "high water absorption polymer in a bentonite base absorbs over 300 times its own weight in water and produces an effective seal against leaking fuels" [Ref. 21:p. 2]. It can stop leaks from "small slits to large holes on jagged, crumpled dirty surfaces...no surface preparation is necessary even though a liquid is flowing around the hole" [Ref. 21:p. 3]. In addition, a new ultrasonic "pig" has been developed that can take 255 pipeline soundings for each 15 mm of forward travel. This translates into 27 million readings for each mile of pipeline to identify the pipewall thickness [Ref. 22: p. 68]. This can enhance spill prevention on pipelines immensely.

Mammoth oil skimmers are being developed with 38,000 gallon-per-minute pumps. "Thirty-six feet in diameter, weighing eighty tons, it would stand high above the sea on a pair of 260-foot submerged pontoons. Although quite expensive (at $35 million), it would be cost effective, considering the Valdez incident cost over $1 billion to date" [Ref. 23:p. 58].

In addition, sanitizer machines are being used that "sweep up sand and shake it through a filter that separates oil traces and tar balls from the sand and redeposits the sand" [Ref. 24:p. 24]. Disker machines are also utilized for cleanup; they turn the sand and expose any oil remnants to oxygen and sunlight, forming tar balls that can be picked up with rakes or shovels [Ref. 24:p. 24].

The U.S. Congress also has demonstrated its concern for oil spill incidents. It recently passed the Oil Pollution Act of 1990 which includes many significant new spill measures, one of the most significant is the requirement for double hulls on tankers by the year 2010 (with a few minor exceptions). An in-depth cost/benefit analysis and effectiveness evaluation will be provided in the next chapter. An assessment of how this government initiative is anticipated to reduce oil spills in future years will also be addressed.

Plans are currently being developed for the world's largest oil spill response network. The Marine Spill Response Corporation (MSRC), an independent, not-for-profit organization" [Ref 25:p. 1] will have an enormous spill cleanup capability. The MSRC will "consist of a Washington D.C. headquarters and five response centers located in the New York-New Jersey (area), Florida, Louisiana, Port Hueneme, CA, and Seattle" [Ref. 20:Attachment 2, p. 1]. The MSRC will have "state-of-the-art equipment and will be able to combat catastrophic spills throughout the tidal and offshore waters of the United States" [Ref. 20: Attachment 3, p. 1]. It is planned to be fully operational in 30 months (from September 1990), and can also be used to assist in smaller spills whenever the Coast Guard determines that local response capabilities are inadequate [Ref. 20:Attachment 3, pp. 1,6].

In addition to current initiatives, such as the MSRC, existing oil spill cleanup facilities, such as Oil Spill

Cooperative and Government Strike Teams are quite capable of cleaning spills of all types.

1. National Strike Force

The Pacific Area Strike Team, located in Novato, California and the Atlantic Area Strike Team, located in Mobile, Alabama, comprise the Coast Guard National Strike Force. The two Teams respond to major oil pollution incidents, provide training, develop cleanup and protection strategies, monitor contractor performance, and draft site safety plans [Ref. 26;lp. 2].

The Coast Guard does not allow unnecessary interference with private enterprise, therefore the "National Strike Force equipment is only used when equivalent commercial equipment is unavailable or insufficient to meet the specific needs of the situation" [Ref. 26:p. 2].

Each team has its designated boundaries. The Pacific Strike Team is "responsible for responding in 12 states in the western portion of the continental U.S., Alaska, Hawaii, and the Trust Territories of the Pacific...the Atlantic Strike Team...covers the 36 states in the East, South, and Midwestern U.S., the Caribbean, Puerto Rico, and the U.S. Virgin Islands" [Ref. 26:p. 4].

Both Strike Teams have vast resources of cleanup equipment. The Pacific Strike Team has 14 skimmers and numerous drocone barges (a flexible rubber bladder used to carry petroleum or other liquids) with capacities up to

246,000 gallons. They have two Mobile Command Posts, equipped with a conference room, sleeping accommodations, advanced communication systems, and are C-130 air deliverable. Skimming barriers (over 600 feet in length), flatbed trailers, tractors, small boats, pumps, absorbent and support equipment are well maintained, in large supply and ready for response [Ref. 26:pp. 12-20]. Most equipment of the Strike Teams is air deployable.

The Pacific Strike Team has assisted in the following oil spill incidents: the Exxon Valdez (1989-240,000 bbl), the American Trader (1989-500,000 gal), the Puerto Rican (1941-200,000 bbl) the Mega Borg (1990-90,000 bbl), and the Chevron Hawaii explosion (1979-10,000 bbl). Since the Team was established 18 years ago, they have been involved in approximately 450 spills [LCDR Lucille (Pacific Strike Team Executive Officer)/Lt B. Bialas conversation on 1 July 1991]. Clearly, the Strike Teams have impressive capabilities which have been utilized effectively in numerous massive spills.

2. Clean Bay Oil Spill Cooperative

The Clean Bay Oil Spill Cooperative (also known as "Clean Bay") is a "coalition of oil, chemical and pipeline companies (i.e., Exxon Company, U.S.A., Chevron U.S.A., Inc., Mobil Oil Corp., Shell Oil Company, Southern Pacific Pipe Lines, Inc...) ...(that) is ready to respond quickly and effectively to virtually any situation involving spilled oil or oil products" [Ref. 27:p. 2]. Their responsibility extends

beyond the San Francisco Bay, covering over "340 miles of California coastline - from as far north as Fort Bragg to Cape San Francisco Martin in the South" [Ref. 27:p. 2]. Within hours of a spill, the staff (headquartered in Concord, California) can "mobilize over 300 trained individuals who, in turn, will supervise up to 2,000 or more workers, depending on the severity of the spill" [Ref. 27:p. 4]. Typically, the first agency to be notified by the spiller is the Coast Guard, who will coordinate the cleanup efforts. Clean Bay, if assistance is requested, could then get involved as the primary contractor.

Clean Bay is a non-profit oil spill cleanup network, "owned by 17 companies...(and) is available to any responsible party, member or non-member" [Ref. 28:p. 1]. Equipment owned or on full-time charter has a "current value of $7 million...(including) a 140 ft. oil spill response vessel, a 10,000 bbl oil storage barge,...12 skimmers,...7 boats...31,000 feet of boom,...151,000 gallons of dispersant... and a dispersant spraying aircraft, (in addition to) trailers and auxiliaries" [Ref. 28:p. 1]. "Four helicopters,...20 vacuum trucks,...four scrapers, four frontend loaders...and tons of absorbents" [Ref. 27:p. 9] are also available.

Clean Bay capabilities are not limited to spill response. Other activities they are involved in include training, maintenance, studies and lightering. Non-spill

activities run approximately "$5.4 million per year and are funded by members...spill cleanup costs are paid by the spiller" [Ref. 28:p. 1]. Major spills that Clean Bay has handled include: the Puerto Rican tanker explosion (1984 of 20,000 bbls), the Shell Oil Spill (1088 of 9,000 bbls) and the Oakland Estuary Spill (1973 of 4,000 bbls); they also participated in the Exxon Valdez Spill (1989-of 240,000 bbls) and the Mega Borg Spill (1990 of 90,000 bbls). Additional cooperatives exist on the West Coast in Los Angeles, Santa Barbara and Seattle, in addition to East Coast facilities, each with immense oil spill cleanup potential [Steve Ricks (Clean Bay Manager)/Lt B. Bialas conversation on 2 July 1991]. As with the Strike Teams, the industrial Oil Spill Cooperatives have tremendous capabilities with a proven track record.

B. ADDITIONAL ALTERNATIVES

As discussed, many initiatives by both government and industry are currently in place. However, there also are additional alternatives for spill reduction, which industry and the government may need to place more emphasis on in the future. For example, improved frames on vessels providing better structural integrity may assist in spillage reduction. Another option is to increase the number of oil-carrying compartments by making each compartment smaller, thus decreasing the potential amount spilled during a rupture. In addition, more dredging may be required, to ensure adequate

depths are maintained for vessels, to help ensure vessels do not run aground. Also, improved fendering of locks, bridges, and other structures would assist in spill reduction [Ref. 33:pp. 41,43,51]. "Situating new structures with greater attention to the operational needs of waterway traffic would also be an effective way to reduce accidents and, hence, the possibility of oil spills" [Ref. 33:p. 51].

Each of theses alternatives would have an impact on oil spill reduction and may need to be addressed further in future years. As has been discussed, much already is ongoing for the reduction of spills; however, the ever-present limiting economical and technological factors must always be kept in mind when we evaluate how much to expect from industry and government.

VI. OIL POLLUTION ACT OF 1990

The United States Congress has demonstrated its concern about oil spill incidents by passing the Oil Pollution Act of 1990. This Act includes significant new spill measures. Due to this Act, many costs and benefits will impact industry, government and society; these impacts will be discussed in this chapter. An effectiveness evaluation of the Act will be included.

A. COST/BENEFIT ANALYSIS

The Oil Pollution Act of 1990 has numerous requirements to be implemented by both government and industry. The expected costs and benefits are many. This section will discuss some of the costs and benefits of the Act to industry, government and society, placing particular emphasis on the new requirement for double hulls, which this author feels is one of the more significant required modifications of current petroleum practices.

1. Benefits

Many benefits will result when the Oil Pollution Act of 1990 is implemented in full. The conformance to all sections of the Act should decrease future spills, resulting in reduced cleanup costs, less product lost and reduced legal expenses. In the long run, industry will obtain a better public relations image, which is a intangible benefit.

Of particular note are the benefits from the double-hull requirement. The most critical is that it has been estimated that double hulls would reduce the outflow from rammings and groundings of single hulled vessels by about 45%, and reduce the amount of outflow from collisions by about 30% [Ref. 33:p. 32]. It has been assessed that double hulls would provide "better protection against spills in minor, low energy accidents...(and) provide only marginally better protection in accidents resulting in large spills" [Ref. 33:p. 60].

For the government, full enforcement of the Act would result in less impact to the environment and better control over the oil industry and its pollution potential. In addition, the U.S. would be seen by the world as a leader in pollution reduction, another intangible benefit.

The benefits to society are: reduced impact to recreation, tourist locations, and individual lifestyles. In addition, fishing industries should be less threatened from oil spill disasters.

In summary, the costs and benefits for the Oil Pollution Act of 1990 are quite numerous and significant to industry, the government and society. To aid in the analysis, an effectiveness evaluation for the double hull requirement is included to provide a realistic picture of its overall impact.

2. Costs

The Act establishes new standards for double-hull tankers. Except as provided by certain sections of the Act, a vessel with a single hull may not operate after 1 January 2010, when operating on the waters subject to the jurisdiction of the United States. This requirement has many costs that are of significance.

Initially, there are the research and development costs to be incurred by the shipowner and by the shipyard. Next, the investment costs are a significant element in the costs of the new regulation. These costs include the shipyard bill for construction or retrofit (including material, labor, overhead (e.g., utilities, taxes, watchmen) and profit) and other shipowner costs, such as training, legal fees, etc. [Ref. 32:pp. 32,53,55]. These cost elements are explained in the following paragraphs.

The costs for a design change will "differ according to whether construction or alterations will be performed in a U.S. or foreign shipyard...any cost estimate must be predicated on an assumption concerning the country the work will be done in" [Ref. 32: p. 54]. In addition, the same design change will differ in cost depending on the location within the U.S.. The "cost of shipbuilding on the West Coast exceeds that on the East Coast by approximately 3-1/2 percent...the cost of shipbuilding on the East Coast exceeds that on the Gulf Coast by approximately 2-1/2 percent" [Ref.

32:p. 54]. In addition, there are many different shipbuilding and repair estimating procedures utilized; ship cost estimation is "often characterized as a "black box" science...(in the U.S. there are almost as many ways of estimating ship construction costs as there are shipyards" [Ref. 32: p. 54].

The costs for a design change can vary depending on when in the life of a ship it is done. Typically, the earlier in the life of the ship the change is made the less expensive the change will be. Obviously it is cheaper to incorporate a change into a vessel on order than one that is under construction; "retrofitting is, on average 75 percent more expensive" [Ref. 32:p. 57].

There are many operating cost changes associated with going from a single to a double bottomed vessel. For example, the "increased structural complexity may make overall repair costs more costly" [Ref. 32:p. 58].

Personnel costs will also be affected by this design change. Because "double bottom vessels increase the risk of explosion (due to the accumulation of gases in the void spaces of the double hull, which may explode) and, hence, danger to the crew...(consequently) the maritime unions may bargain for an increase in wages for crew members" [Ref. 32:p. 58] [Ref. 33:p. 44].

Insurance premiums may be affected by the design change. Premiums could decrease because "double hulls are

expected to decrease collision damage and resulting oil spills....(but) double hulls also may increase the probability of vessel explosions and crew danger" [Ref. 32:p. 59] thereby cancelling the decrease.

The cargo carrying capacity of the vessel could change due to the design change, because the double hull replaces fuel storage space [Ref. 32:p. 60]. Additional repair parts could be required because of the increased structural complexity [Ref. 32:p. 58, 60]. In addition, the new vessel design regulation could "necessitate crew drills or crew attendance at certain training institutions" [Ref. 32:p. 60]. Moreover, the administrative cost of increased paperwork must be accounted for (i.e., to monitor the added requirements for repair parts, training, drills) [Ref 32:p. 60].

When a vessel makes a special trip to a shipyard or extends its stay at a shipyard for equipment installation, this "time lost to productive uses represents a real cost to the owner in addition to the shipyard or manufacturer cost of installation" [Ref. 32:p. 62]. On the market, demurrage costs per day can vary from $8,875 for a 55,000 DWT tanker to $85,000 for a 390,000 DWT tanker [Ref. 32: pp. 59,60,86]. These values provide a measure of the potential loss from not having that vessel operating.

The identified costs due to the requirement for double hulls from the Act are quite large. However, when compared to typical legal claims from spills, there is a definite

incentive to reduce spills. For example, in 1990 dollars, claims approximated "$2800 per ton of oil spilled. The startling exception is the Exxon Valdez case, in which costs could reach $90,000 per ton" [Ref. 6:p. 156]. In addition, clean up costs can range up to $38,000 per ton [Ref. 6:p. 160].

Additional requirements from the Act, and their impact, are as follows. New tank level or pressure monitoring devices to ensure people are warned of impending accidents are necessary. This could result in considerable expense to industry due to the large numbers of individual tanks (typically between ten and twenty) on each tanker.

In addition, tank vessel manning has many new restrictions; i.e., licensed seamen are not permitted to work more than 14 hours in any 24 hours or more than 35 hours in any 72 hour period, except in an emergency or drill. Depending on how current ships and schedules are established, this could result in additional manning for ships (for better safety), but also higher costs to the industry.

New minimum standards for plating thickness and periodic gauging of the plating thickness of vessels are to be established which allow vessels to continue to operate. These will result in considerable costs to the industry for compliance, especially if the tankers do not meet the minimum standards of thickness currently.

Government costs, due to this Act, are also substantial. As a result of this Act, new inspection requirements have been established for skimmers, booms, and vessels, and new requirements for unannounced drills are to be established. New regulations will establish expanded or improved vessel traffic service systems on the U.S. navigable waters to reduce the risks of collisions, spills, and damage associated with that traffic. This will require additional government funding, manpower and documentation.

The Act has required a study to be conducted to evaluate the adequacy of qualifications and training of crew members on tankers, and their ability to prevent or remove a discharge of oil from their tankers. Additional study requirements include: evaluate the adequacy of navigation equipment and electronic means of position reporting and identification of tankers, and evaluate the adequacy of navigation procedures under different operating conditions, including variables such as: speed, daylight, ice, tides, weather and other conditions. These requirements will necessitate more government funds.

The Act requires a government study to determine whether tank liners or other secondary means of containment should be used to prevent leaking. In addition, the government is required to conduct a study to ensure that tankers are equipped with proper communication capabilities. Again, government funding is required to support the study.

The government is required to monitor and approve the new guidelines for the area contingency plans (currently, each *fueling* location is required to have contingency plans developed, in case of a spill (i.e., how they will react, clean it up); the new Act provides for stricter guidelines for the plans). This will require government funds.

New regulations for foreign tank vessels have been established. The need to periodically evaluate the manning, training, qualification, and watchkeeping standards of a foreign vessel to ensure they are at least equivalent to United States law, or international standards accepted by the United States, has been mandated to allow the foreign vessel to operate in U.S. navigable waters. These requirements will require substantial government resources, i.e., manpower and documentation, to monitor.

New regulations on criminal record reviews, and *licensing or certification of registry holders are mandated*, requiring government funding. New alcohol and drug testing requirements have also been established.

B. EFFECTIVENESS EVALUATION

The double hull requirement (in addition to the other requirements of the Act) will cost industry money, which will "ultimately be borne by the consumer" [Ref. 33:p. 61] in paying at the pump (or via taxes to fund the new government requirements). However, in attempting to reduce spills, "on the basis of cost-effectiveness the double hull is among the

best values....(ultimately) when they are fully phased in, double hull tankers will cost about $700 million per year, or about one or two cents per gallon of gas at the pump" [Ref. 6:p. 13]. From this nominal cost, double hulls should help prevent the spill of "between 3000 and 5000 tons of oil into the ocean each year" [Ref. 6:p. 13]. They "offer the greatest potential for tank penetration reductions" [Ref. 34:p. 39].

Table XI provides an in-depth effectiveness evaluation which identifies the relative impacts that tankers with and without double hulls will have on industry, government and society.

In the evaluation, the "Weights" (W) were subjectively assigned by the author (a certified Fuel Intern of Naval Supply Center, Charleston, South Carolina and a former Petroleum Officer of the Naval Base, Rota, Spain) based on a group discussion (the group consisted of three personnel, including another certified Fuel Intern) during a Policy Analysis course, MN4145, project, at the Naval Postgraduate School. These weights identify the relative importance that each characteristic has on industry, government or society. The sum total of the weights equals 100. In addition, the "Relative Importance/Capability" (S) values were also subjectively assigned, (in the same manner as the "Weights") identifying the relative impact a tanker, with or without a double hull, has on the denoted characteristic. Each of these factors, (S) and (W), were then multiplied to obtain the

product "WxS". The sums of "WxS" for tankers with or without double hulls identify the relative impacts on government, society, and industry from the evaluated characteristics.

TABLE XI

EFFECTIVENESS EVALUATION

			RELATIVE IMPORTANCE/ CAPABILITY (S)	
ITEM	WEIGHT (W)	CHARACTERISTIC	WITH DOUBLE HULL	WITHOUT DOUBLE HULL
1	20	DECREASE SPILLS	20	15
2	18	DECREASE PRODUCT LOSS	18	13
3	10	CLEANER ENVIRONMENT	10	7
4	6	LESS IMPACT TO FISHING INDUSTRY	6	4
5	6	LESS IMPACT TO TOURIST/ RECREATION FACILITIES	6	4
6	5	LEADER IN POLLUTION REDUCTION	5	3
7	15	DECREASE LEGAL EXPENSES	15	3
8	15	BETTER PUBLIC RELATIONS FOR INDUSTRY	15	4
9	5	"CONTROL INDUSTRY"	5	0
SUM (W) = 100		SUM (W x S) =	1396	772

Consequently, tankers with double hulls (WxS sum = 1396) are significantly (81%) more important than tankers without double hulls (WxS sum = 772) for society, government and industry as a whole.

The maximum constraint for each (S) value is determined by the weight (W) for each characteristic, and the minimum value for any (S) is zero. This procedure was also part of the course content of MN4145. Consequently, the (S) value can fall anywhere between zero and the weight value. For example, in item #1, the maximum value for (S) is 20, (the weight for the "decrease spills" characteristic) while the minimum the (S) value can be is zero.

A full explanation for each (S) and (W) value is hereby provided:

ITEM 1. For Item 1, (a very critical item, therefore it received a high value for (W) of 20), tankers with double hulls (S = 20) will decrease spills more than tankers without double hulls (S = 15). As identified previously, double hulls should preclude between 3000 to 5000 tons of oil from being spilled annually.

ITEM 2. Tankers with double hulls (S = 18) will allow for less product loss than tankers without double hulls (S = 13). The (W) value is important, but not as critical as item 1, therefore the value 18 is assigned.

ITEM 3-5. Because of less product loss (as noted for Item 1) tankers with double hulls will promote a cleaner

environment (S = 10), and provide less impacts to the fishing industry (S = 6) and tourist/recreation facilities (S = 6) than tankers without double hulls (S = 7,4,4 respectively). For item 3, the (W) value is less significant than for items (1-2), but more critical than items (4) and (5); the (W) values of 10, 6, 6 were therefore assigned, respectively.

ITEM 6. Less product loss will allow the United States to become a better leader in pollution reduction, if double hulls exist in tankers (S = 5) than if tankers do not have double hulls (S = 3).

For items (6) and (9), the weight is the least critical of all assigned, consequently a value of 5 is utilized.

ITEM 7. Having less product loss results in fewer legal encounters, thus double hull tankers have a much higher "S" value (of 15) vice tankers without double hulls (S = 3). This has a significant impact to the stockholders with tankers having double hulls.

ITEM 8. Providing less product loss will promote better public relations for industry; thus, "S" is substantially higher for tankers with double hulls (of 15) than tankers without double hulls (S = 4). This item is also very critical to the stockholders with double-hull tankers.

Both items (7) and (8) are highly critical characteristics, thus they were given a high weight of (W = 15).

ITEM 9. Lastly, the government will have a stronger control over industry, by imposing the double-hull requirement

(S = 5). Government will show its lack of control of industry if double hulls do not exist (S = 0).

Consequently, a substantially higher effectiveness for all of the characteristics (Items 1-9) can be obtained by the addition of the minimal/negligible increase in cost (in fact the cost can almost be considered fixed) for double hulls. The conclusion that can be reached from this analysis is that for the small cost of one or two cents per gallon, a marked increase for many beneficial factors/characteristics can be obtained by having double hulls vice not having double hulls.

C. SUMMARY

The impact of the Oil Pollution Act of 1990 is quite significant. When fully in effect (i.e., by the year 2010 for the double hull requirement, etc.) the environment should have a reduced potential and occurrence of spills, aiding man's persistent quest to live in harmony with nature. The risk of spills cannot be eliminated in total, but reducing it to a level acceptable to society [Ref. 6:p. 35], within the economical and technological bounds of man, is a constant goal for which we must, and never should, stop striving for. In addition, opportunity costs must continually be evaluated to ensure industry does not expend an excess amount of money on oil spill prevention and innovative cleanup procedures, and neglect more critical global petroleum concerns, such as locating petroleum sources.

This Act and the initiatives identified in Chapter V are intended to aid in oil spill reduction. However, new developments, alternatives and ideas must continue, and be implemented, as is economically feasible, to ensure oil spills are kept to a realistic and acceptable minimum.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Providing a safe, acceptable method of petroleum transportation, and ensuring the environment is as well protected as is technologically and economically feasible, is highly critical. As identified, the safe transportation of liquid petroleum shows a track record that has been improving. And, when spills do occur the capability for cleanup is constantly getting better. To put the movement of liquid petroleum into a realistic perspective: oil spill damage is not as "bad" as the media typically portrays.

"It has been assumed that oil spills are the inevitable price which must be paid for an advanced civilization" [Ref. 2:p. 3-1]. But, with the efforts of industry and government, many actions have been taken to decrease these undesirable events. With the Strike Teams, the Co-ops, the Oil Pollution Act of 1990, the future MRSC, and the many new industrial programs underway (i.e., new skimmers, new barges, new liners), not only should oil spills continue to decrease in the future due to better prevention procedures, but their environmental impacts should also be minimized due to technologically more advanced cleanup methods.

The time may come when oil will be replaced by other energy sources, but in today's demanding society, where

millions of gallons of fuel, of all various types, are moved each day, the current number of spills needs to be labeled acceptable due to man's present capabilities. One must also keep in mind that for any oil spill, "the forces of nature determine the success or failure of a cleanup...winds, tides temperature, location, and luck are irreducible factors" [Ref. 9:p. 69]. Technology for prevention and cleanup is a major part of the solution. But a "realistic assessment of what is and what is not a true environmental hazard" [Ref. 7:p. 661] needs to be addressed. As has been noted in Chapter II, the environment has a way of taking care of its own. As it comes from the earth, oil also returns, with a negligible long term effect. Consequently, sound policies, in addition to a solid perspective, need to be maintained on spills and their impact.

B. RECOMMENDATIONS

Industry and government need to continue efforts in spill reduction, prevention and cleanup. When the Oil Pollution Act of 1990 is implemented in full, it will provide an effective impact in reducing spills. The MSRC needs to become a reality to provide additional safety to the environment. Continual research in oil spill cleanup and prevention needs to persist, as is technologically and economically feasible. Increased efforts need to be made on tanker design, compartment size, and vacuum tank systems to ensure the least amount of oil is spilled when an accident occurs. Assessments on current training practices need to be continually reviewed

and enhanced when necessary. Safety practices in all oil operations must be continually stressed and reviewed to ensure safe vessel passage. In addition, future waterway structures need to be examined and analyzed fully, to provide the least accident-prone environment.

Consequently, although much has been and is being done for oil spill prevention and cleanup, efforts must not slow. Emphasis in this all-important aspect of petroleum movement must never take a back-seat position. Progress is being made and must continue.

Is "enough" being done to protect the environment (as the title of this paper asks)? Obviously this is a judgement call. "Enough" environmental protection may not be attained until zero spills occur, but technologically and economically this is a hurdle of immense proportions. It has been assessed that "a reduction of oil pollution to zero was impossible if oil was to continue to be transported by water" [Ref. 33:p. 53]. Consequently, efforts must continue in this critical aspect of petroleum management to ensure the highest potential caliber of petroleum movement safety, to provide the highest possible protection to the environment. This should result in a continuous reduction in oil spills, and their impacts, in years to come.

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